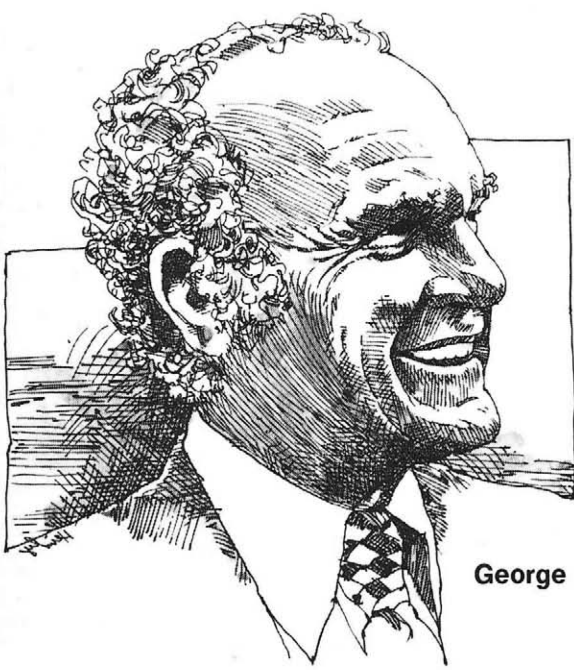
record keeping, and reporting will greatly increase laboratory costs and reduce research productivity. Analogous costs also are encountered in plant operations. Plant capital and operating costs will continue to be substantially affected by increased safety and antipollution requirements. Growing publicity and consequent public attention to accidents involving transportation of hazardous chemicals may encourage users to locate closer to their source of supply.

Over the coming years it will be up to the chemical industry and its trade and professional associations to inform the public of the technological and useful nature of the industry's activities and of the work it is doing to protect society from known hazards and unknown risks. This information is essential if the industry, whose costs eventually must be borne by the public, is not to be subject to unwise legislation resulting from ignorance (even possible panic, as in the case of the "Three Mile Island Syndrome"). It is also essential for the industry to conform to the highest ethical standards that the public is entitled to expect of it.

The chemical industry, as is the case with other high-technology industries, historically has offered encouragement to small, innovative organizations. There has been considerable recent attention within the federal government to factors, particularly taxation and regulatory policy, that adversely affect the innovative trend in the U.S. Although there has been some tax relief for capital gains, which is helpful, there is still oppressive taxation and regulation still must be borne by an innovative individual, or company, who creates a successful business. It is hoped that this situation will continue to be examined and that the desires of some pressure groups for income redistribution will not be used to discourage innovation. Certainly, heavy taxation, when coupled with the uncertainties arising from inflation, feedstock manipulation, and government regulation shifts, can slow the rate of technological advance in the industry. □



CHEMISTRY IN THE **1980's**

EDUCATION

George S. Hammond, Allied Chemical

George S. Hammond, director of chemical dynamics for Allied Chemical, joined Allied last year after an innovative academic career as a teacher, researcher, and administrator. Although principally known as an academician, Hammond has had a long-standing connection, as a consultant, with the chemical industry. Born in Auburn, Me., in 1921, Hammond studied chemistry at Bates College and Harvard, from which he received a Ph.D. in 1947. He taught at Iowa State (1948–58) and Caltech (1958–72), where he was chairman of the division of chemistry and chemical engineering. He later was vice chancellor for natural sciences at the University of California, Santa Cruz, and foreign secretary of the National Academy of Sciences. His research has included such areas as free radical reactions, organic photochemistry, theory of reaction rates, and the kinetics and mechanisms of reactions of metallic compounds with molecular oxygen. His honors include ACS awards in petroleum chemistry (1961), physical organic chemistry (1968), and chemical education (1974), topped by the Priestley Medal for 1976.

I can make only one prediction with confidence concerning chemical curricula during the coming decade, namely that they will bear considerable resemblance to the curricula of the 1970's. For better or for worse the rate of change in chemical education is slower than the rates of change characteristic of many other parts of our social system.

Although I have complained about the widening gap between chemical education and active chemical science in the past, I am not entirely convinced that slow change in educational practice is bad. If education were to reflect accurately the rapid surges of new direction and accomplishment in pure and applied chemistry, the curricula might become so erratic that they would seem, and perhaps be, aimless. Despite this reservation I cannot resist the temptation to go ahead and prescribe the directions in which I believe chemical curricula should change during the next 10 years.

In principle, curricula should be molded to implement whatever it is that education is intended to accomplish. Although that pronouncement may seem like a pious aphorism, it lies at the root of many problems in chemical curricula. They contain numerous, sometimes conflicting, agenda items that are rarely explicitly recognized by curriculum planners, teachers, or students.

One of the powerful drives—derived from a European heritage that goes back at least five centuries—of the educational system is to select students for upward social mobility. Curricula are designed to prepare students to perform well in discriminating examinations that they face at the end of various educational stages, and in more examinations set for them at still higher levels on the educational ladder. In some parts of the world, including the U.S., this goal is questioned and shoved into the background. However, it still lurks as the strongest motivation in the minds of many students who refuse to be diverted from their real purpose by loosely articulated and fanciful goals suggested by their teachers.

For the small number of students who will become professional chemists or chemical engineers, the curriculum should provide some foundation for effective performance in their life work. The same is true of students who are preparing for other professions, such as medicine, engineering, agriculture, or even commerce, in which knowledge of chemistry or chemical technology may be of some value. Problems arise because the practical needs of people in these different fields vary and because students at the earlier educational levels do not know which, if any, of these professions are their career goals. In the U.S. we may exacerbate this problem by delaying career choice until a relatively late stage in a person's life. The advantages of such delay in decision-making have been frequently enunciated but they do pose substantial problems for educators working at the secondary, tertiary, and even graduate levels.

A great deal has been said and written about the need for science education to produce scientifically "literate" citizens. The objective is clear and reasonable but means of implementation are far from obvious. The problem is illustrated by numerous discussions of "chemistry for the chemist vs. chemistry for the citizen." The phrasing of the question belies the viability of any solution. There is a clear implication that other citizens are not going to understand chemistry and that the understanding of what chemistry is about, proper for nonchemical citizens, is trivial for the chemist. When stated blatantly, neither proposition is attractive to either students or teachers so we tend to put the problem aside and hope that it will go away.

As a last recourse in seeking a purpose for chemical education we seize upon the proposition that it is an exercise in training and developing the intellect. It is surely true that young intellects do grow when stimulated by the educational process and it is also true that the models with which chemists formulate their view of the universe form a marvelously intricate matrix capable of stimulating any intellect. This point of view has powerful weight in the self-justification processes of both chemical researchers and chemical educators.

The concept may lose some of its attraction when one realizes that the game of chess also presents limitless intellectual challenge but does not find its way into most educational programs as a mind builder. Even though intellectual training cannot survive as a principal justification for chemical education, we do well to recognize that it is part of the hidden agenda of many teachers and most textbook authors.

Chemical curricula are discussed from two principal viewpoints, methodology and content, frequently as though the two were entirely unrelated. Hard-core chemists tend to emphasize content and often derogate methodologists as being preoccupied with style to the point of becoming totally indifferent to the content, if any, of their courses. Although my concerns tend to emphasize content, I am willing to grant that some methods commonly encountered in the teaching of chemistry appear to be designed to make learning as difficult and meaningless as possible. Ten years ago there was a flurry of active attention to methodology throughout education and even the bastions of chemical pedagogy were invaded. The action has now largely subsided but I believe that some worthwhile experiments were conducted with better results than are generally appreciated.

Perhaps the most outstanding example was the significant number of self-paced courses (such as the Keller Plan courses developed by psychologist Fred Keller) that were developed. It was certainly demonstrated that given guidance and reasonable study materials, many students learned very well, perhaps even better, without traditional lectures. Unfortunately, these experiments seem to be on the wane at this time for several reasons. First, students have become wary of almost anything labeled "unconventional." Second, teachers, who anticipated that after an initial heavy investment of effort they would have a self-propelling course, were disappointed to find that the Keller course demands the same continual effort as a good lecture course. Furthermore, presentation of a self-paced course to a large class requires more tutorial help than usually can be provided.

Some methods commonly encountered in the teaching of chemistry appear to be designed to make learning as difficult and meaningless as possible

A great deal of time and energy have been devoted to development of audiovisual teaching aids and computer-assisted instruction. Although the run-of-the-mill products of such programs have been uninspiring, I believe that some high-quality products have emerged. Unfortunately, I do not believe that most instructors give much creative thought to skillful use of such materials so that they are woven into the fabric of courses rather than being tacked onto the edges for largely decorative purposes. For example, I believe that even the best videotape should not just be played through in its entirety for a class, but should be stopped, started, and edited so as to become an addition to the teacher's own presentation.

I am convinced that the content of chemical curricula at all levels is important. I do not, however, believe that there is a single best package of contents for any individual course or for any preprofessional curriculum. Students, teachers, and social context vary enormously and some of the differences should be reflected in curriculum content. I also believe that strict uniformity in preprofessional studies is a dire mistake for a country of any size because it will work against production of a population of scientists having the diversity needed.

In many countries, uniformity of examinations and syllabi locks curricula into nearly fixed form and often creates educational disasters. In this country, constraint by examination is not an acute problem, although most high school teachers are concerned about the scores their students make on standardized tests used by college admissions officers and many college teachers are somewhat influenced by the Graduate Record Examinations. However, I do not think that standard examinations are principal factors in the homogeneity and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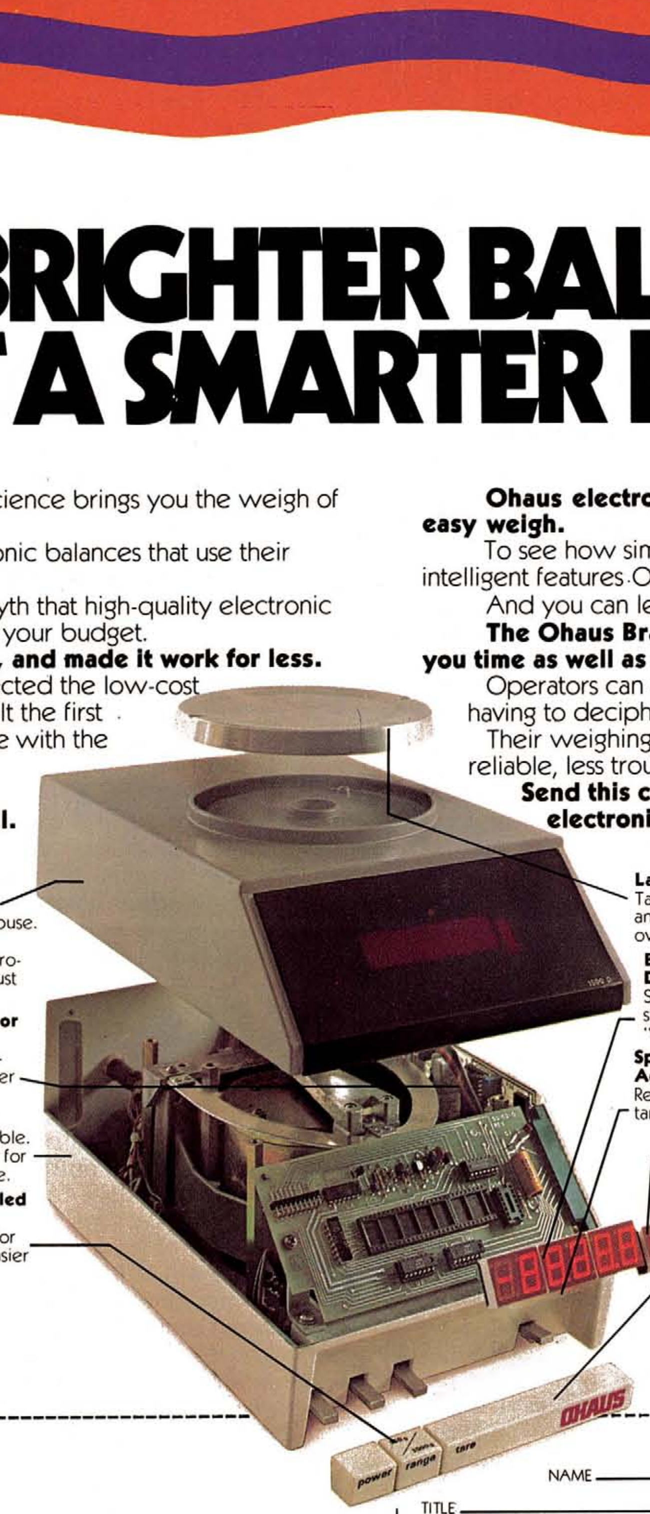

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PHONE NUMBER (Area Code) ______________________ rather static character of chemistry (and other) curricula in the U.S.

Fear is a principal reason for conservatism in curriculum development—fear of the work required to make extensive changes well and fear of failure of the enterprise. Those fears are well founded. I have participated in a number of experiments with course or curriculum modification. They were all a lot of work and none were as successful as I had hoped. One of my biggest disappointments was the glee with which even some of my closest colleagues identified and described shortcomings they perceived in my teaching experiments in an effort to discredit the entire enterprise.

In 1966, I made suggestions for substantial modification of undergraduate college chemistry curricula (C&EN, Nov. 14, 1966, page 48). The ideas received a good deal of publicity and for a short time the pros and cons of the "Hammond curriculum" were debated hotly. I am told that I was accorded the high honor of being hanged in effigy in one distinguished department. Although some people, notably the faculty at the State University of New York, Albany, made extensive modifications of their undergraduate programs, there has been no strong move to adopt my suggestions even in modified form. In retrospect, I realize that making those suggestions was a rather lightweight contribution to chemical education. To implement change, people need help, primarily in the form of new textbooks. I did undertake to organize a textbook-writing activity and with coauthors began some serious writing. The work never came to fruition. The textbooks did not emerge quickly because writing a good text is always hard work and because my collaborators and I found that translating concepts for substantially reorganized curricula into coherent and pedagogically sound form is doubly difficult.

Examination of textbooks . . . shows a preponderance of material that is far removed from what most chemists are now doing in research

I now wish that the textbook series, as conceived, had been put together. I recognize that the best we could have done would probably have been a failure in the marketplace and a wound to author egos. However, something would have been started and by this time others might have written better books and a real trend toward teaching chemistry as structure, dynamics, and synthesis might be under way.

A principal reason for urging restructuring of curricula was my belief that preprofessional students were not receiving optimal education to prepare them for work in the existing field. I continue in that belief. Examination of the textbooks used by undergraduate chemistry majors shows a preponderance of material that is far removed from what most chemists are now doing in research and development. The practice is defended by the assertion that students should be taught basic principles that will serve as an underpinning for whatever they may do in the science. To argue against such a proposition would be heresy. However, I do not think that current textbooks stand up very strongly as models of wise choice of materials. In a brief presentation I cannot hope to document such a proposition convincingly, but I will offer a few bothersome examples.

Textbooks of organic chemistry (including my own) contain repeated reference to the synthetic utility of reactions and usually include chapters devoted to strategy in multistep syntheses of natural products. I find the chapters interesting but am hard pressed to say exactly why. Probably part of the reason is that I grew up in chemistry during the time when the late Robert B. Woodward was creating a major revolution in the way in which such syntheses were approached. It was a thrilling time, especially to those who knew the man and were exposed to the brilliance of his mind. Despite yeoman efforts by authors, only a hint of that intellectual genius shows in the textbook accounts of syntheses, and little wonder, since thorough analysis of any Woodward masterpiece would require a book in itself.

Most students do not find the material nearly so interesting as I do, and my own interest in complex syntheses has waned considerably over the years as their number has multiplied. Furthermore, synthetic work of this kind is practiced by only a handful of chemists. Most chemists do entirely different things today. Many more are now involved in study of some branch of organometallic chemistry (most commonly related to catalysis), a subject barely treated in most organic textbooks (again including my own).

The fact is that the modern organometallic chemists do very well without having had any directly relevant preparation, unless they took courses in advanced inorganic chemistry. This speaks well for their intelligence and adaptability and perhaps means that it does not matter what students learn in their early course work as long as they learn something. I find it hard to adopt such a cynical attitude and believe that chemists and chemistry would fare even better if undergraduates learned a little more about the basics in the areas where they are most likely to work.

I see the same kind of problem in textbooks of physical chemistry. There is usually a great deal of emphasis on formal quantum mechanics and theories of rate processes, but relatively little reflection of the methods usually used by people now doing theory of molecular structure or the kinetics of reactions in inhomogeneous systems. Surface chemistry, surely one of the most active areas of chemical research at this time, is given little or no attention in any undergraduate chemistry course.

Mention of surface chemistry brings me to my final point. Teachers and textbook authors have little taste for discussion of subjects that they don't understand. This is both human and understandable. After all, teachers are supposed to be sources of knowledge rather than nonknowledge. The result is unfortunate because students learn only about what has been done, rather than what remains to be done. Virtually all textbooks are written with a ring of final authority. As a consequence, fields which they purport to represent seem much less interesting than they should. Furthermore, the most thoughtful students are likely to regard their texts as mildly fraudulent and their conscientious classmates develop a sense of frustration and inferiority because it seems that they should be able to solve everything if only they really understood what is in their books.

The main theme of any course has to be built around what is known and understood. However, it should not be impossible to weave in a pattern of the unfolding field by carefully chosen examples of things that we cannot do or do not yet understand. These should reflect the chemist's view of what he or she wants to accomplish.

I do not think that global ambitions—"clean up the environment" or "solve the energy problem"—are very effective. In my own excursions in this kind of teaching, I find that students respond well to specific problems that I want to solve, but cannot. The following are specific examples:

• Find a good reaction for synthesis of amines by addition of ammonia to alkenes.

• Predict the structures of crystals using molecular structures and some theory of intermolecular interactions.

• Find an effective catalyst for hydrogenation of nitrogen to ammonia at ambient temperatures.

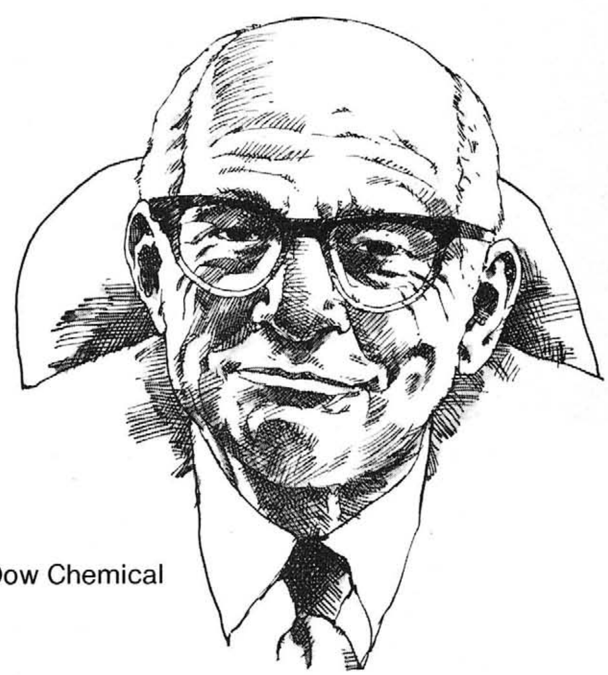
Note that each of these problems is one that has been the subject of considerable research and about which we know something. This feature is useful because one can teach something about methodologies for seeking solutions to problems without seeming to imply that the methods inevitably work. I have no objection to much more exotic challenges, such as "formulate a chemical dynamic model for all the coupled reactions that occur in a living cell." When I discuss problems of such complexity I find that I rather quickly run out of significant things to say, which may not be regarded as a great loss to my audiences.

Perhaps one important barrier to presentation of unsolved problems of the more modest type is that preparation for such teaching requires more work than presentation of well-established fact and theory. It can be a bit embarrassing to discuss an unsolved problem only to find that it has been solved. At one time I regaled a class with a learned discussion of the classical failure of chemists to prepare perbromates, only to be informed a few days later by a student that Evan H. Appelman of Argonne National Laboratory had reported the synthesis of $RbBrO_4$ the previous month. Fortunately, I had not in my discussion sided with those who had theorized that perbromate ion could not exist!

My principal conclusion was stated in my first sentence. I also believe that both the style and content of chemical curricula are worthy of continual attention and are in need of modification. I strongly favor modifications that direct attention of students to current activities in chemistry and to goals that motivate those activities. □

CHEMISTRY IN THE **1980's**

INDUSTRY



Carl A. Gerstacker, Dow Chemical

The chemical industry is rapidly coming face to face with what we may call the "weighty eighties." During the decade ahead, the problems facing the industry will be weighty, and so will the volume of its product. If all goes well, its earnings will be weighty, too.

Perhaps the single most critical factor confronting the industry as it heads into a new decade is the nature of its continuing relationship with the federal government. During the 1970's, the government officially declared itself the Big Brother of the industry with the passage of the Toxic Substances Control Act (TSCA) and other legislation; in the years ahead we will find more precisely how much trust the government has (or doesn't have) in the industry's capacity to act in the public interest.

The relationship no longer involves a question of whether government will look over the industry's shoulder; it is one of how much, how closely, and in what activities the government and its watchdogs will monitor those of us who manufacture chemicals. During the eighties the industry will either regain some of its freedom, which greatly diminished during the seventies, or learn to live with the shackles of overregulation.

In Carl A. Gerstacker's long career as an executive in the chemical industry, he has served both Dow Chemical and the industry as a whole with distinction. Since his retirement in 1976, at 60, as chairman of Dow's board of directors, he has continued as a member of the Dow board and chairman of its finance and compensation committees. Born in Cleveland, Gerstacker received a degree in chemical engineering from the University of Michigan in 1938 and joined Dow immediately after graduation. He returned to Dow in 1946 after six years in the Army, where he rose to the rank of major in the Ordnance Department. He was elected a director in 1948, named treasurer of the company a year later and a vice president in 1955, and became board chairman in 1960. During the 16 years that he was Dow's top executive, company sales rose nearly sevenfold to almost \$5.7 billion. Gerstacker also has been chairman of the Manufacturing Chemists Association (now the Chemical Manufacturers Association) and president of the Synthetic Organic Chemical Manufacturers Association. He serves as a director of several companies in addition to Dow.